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Atmospheric Measurement Techniques Discussions

Interactive comment on "An urban microwave link rainfall measurement campaign" *by* Thomas C. van Leth et al.

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REVIEWER: General comment: The manuscript describes dedicated experiment designed to investigate different phenomena influencing rainfall retrieval from microwave links. Several microwave links were installed over same path and equipped with time lapsed cameras shooting antenna surfaces and the link path. In addition, array of disdrometers completed with rain gauges were placed along the link path. Finally, additional observations form nearby weather station such as temperature, humidity or wind speed were used to interpret phenomena occurring during the measurement campaign. The manuscript goal is to provide comprehensive overview of different phenomena causing attenuation of microwave links and evaluate their relevance for rainfall intensity retrieval, specifically to the rainfall retrieval algorithm as suggested by

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Overeem et al. (2011 and 2016). The first goal is scientifically relevant as i) it might improve understanding of uncertainties affecting microwave link rainfall retrieval and ii) description of attenuation patterns from other phenomena than rainfall is crucial for improving baseline separation algorithms. The presented experimental setup is very well suited to provide reliable dataset to reach this goal. The second goal is bit too specific to the selected processing algorithms (Overeem et al. 2011 and 2016).

RESPONSE: We thank the reviewer for the positive assessment of our paper. We acknowledge that the second stated goal is too specific and this does not in fact reflect our actual intentions. The mention of the algorithms of Overeem et al (2011 and 2016) is intended merely as an example of possible integration in existing retrieval schemes and not as a goal for this paper. The text as written in P2L27-29 does not properly reflect this and we will revise it.

REVIEWER: The manuscript focuses on describing different phenomena causing link attenuationon several selected events. Overall statistical evaluation is mostly not provided which hinders quantitative assessment of the influence of these phenomena on microwave link rainfall retrieval. Results are often presented qualitatively in subjective manner (e.g. 'link is remarkably stable') even in cases where it could be easily described quantitatively, for more details see specific comments.

RESPONSE: We agree with the reviewer that many specific instances can be easily described more quantitatively and we will do so in the revised manuscript. Please see our resposes to the specific comments for more details.

REVIEWER: Authors should distinguish in the whole result section more properly if the attenuation occurs along the link path or if it is rather related to hardware of microwave link radio units/antennas. The ambiguous cases should be then properly discussed and possibly confronted with radio wave propagation theory or results of other studies.

RESPONSE: We will add clarification to the different parts of the results section where applicable. The ambiguous cases are mostly illustrative and a more thorough analysis using radio wave propagation theory is beyond the scope of the current paper, but will be part of future work. Moreover, we are not aware of similar ambiguous cases described in the scientific literature.

REVIEWER: The manuscript is well structured, however, stylistics might be still improved, e.g. paragraphs in the result section could be more concise and fluent.

RESPONSE: We will carefully re-read the manuscript and apply modifications where applicable.

REVIEWER: Specific comments:

P7L28: Results and discussion section: The results of microwave links are in the text mostly presented in mm/h although figures show also dBs. I strongly recommend to present the results also in dBs and compare them with theoretical rain induced attenuation from disdrometer data (eq. 3). The main reasons are these i) the uncertainties arising from imperfect separation of rain-induced attenuation are mixed with uncertainties arising from rainfall-attenuation powerlaw model, i.e. variability of α and β parameters (Tab. 2) during different rainfall events and uncertainties due to path-integration of attenuation and nonlinearity of power-law model. This hinders interpretation of results. ii) Substantial part of link attenuation unexplained by raindrops are hardware related errors (e.g. due to wet antenna or quantization noise). Such uncertainties expressed in mm/h apply only to links of the same lengths as in the experiment. iii) Most of the literature concerning microwave link propagation and different phenomena influencing radio wave attenuation (including wet antenna attenuation) express results in dBs.

RESPONSE: We completely agree with the reviewer on this point. We will add an extra panel to figures 5, 6, 8, 9, and 13, showing attenuation in dBs including the disdrometer-derived theoretical attenuations.

REVIEWER: P8L5: It is stated here that in the presented event there are ‘no attenuation-inducing influences other than rain’, however, this is inexact as the radio waves are during this event for sure attenuated e.g. by atmospheric gases, there is a free space loss, etc.

RESPONSE: This is meant as "no attenuating phenomena contributing to the dynamics of the signal". We will clarify this in the text.

REVIEWER: P8L33: There are certainly various attenuating phenomena (see comment P8L5) influencing link attenuation, and drop down in the RAL link signal level has probably some (uknown?) reason.

RESPONSE: We agree. We will alter the text on this point.

REVIEWER: P9L4: ‘remarkably stable’ or ‘uncertain baseline’ is very subjective description. Pleasequantify.

RESPONSE: Agreed. We will provide numbers in the revised version.

REVIEWER: P9L17-20: The causes of outliers and overestimation discussed in these lines are speculative. The experimental design should enable investigate unexpected behavior of links much more specifically thanks to reliable ground truth, cameras, etc. For example, it is stated here that ‘overestimation and outliers could be attributed to attenuating phenomena ... erroneously processed as rain in the basic algorithm’. It should be, however, possible to check against disdrometer data if the errors are due to the processing algorithm. Similarly, errors introduced by k-R model can be estimated and it should be verified if they can explain underestimation.

RESPONSE: We have added to this response a new figure illustrating the relation between link attenuation and disdrometer-derived theoretical attenuation at the relevant frequencies. We also added an updated version of figure 7. These pictures show very similar results. Therefore, the R-k power law model introduces very little additional error. This is further supported by the high goodness-of-fit found for the R-k model itself. We will further clarify this in the text.

REVIEWER: P10L22-24: Please quantify the magnitude of oscillations.

RESPONSE: Agreed. We will quantify this magnitude.

REVIEWER: P10L33: Is the 90 % humidity threshold selected arbitrary, based on radiowave propagation theories, or estimated by regression itself? Please indicate.

RESPONSE: The reason for this is made clear in P11L8-11 when talking about dew. We will re-arrange the text so that this is clear when the 90% threshold is introduced.

REVIEWER: P11L13-15: The statement that 'the temperature dependence of the Nokia link is drowned out in the noise' is speculative as you cannot prove there is a temperature dependency if it is 'drowned out in the noise'. If you can prove it (at reasonable confidence level) it is then not 'drowned out in the noise'.

RESPONSE: We acknowledge that this phrasing is sloppy. We have rephrased: "There is no evidence of a temperature dependence of the Nokia link here, even though one would expect it based on the findings from 14-24 April."

REVIEWER: P11L19: Please indicate in the text the duration of antenna wetting and drying quantitatively. The figures depict too long period to distinguish if the processes take place only few minutes, tens of minutes or few hours.

RESPONSE: The timescale of these events is in the order of hours. We will add this information to the text.

REVIEWER: P11L31-32: Please describe more precisely what is meant with 'quite different pattern'. Different range, variability, autocorrelation structure, ...?

RESPONSE: We refer here to the autocorrelation structure. We will clarify this in the text and provide more detail.

REVIEWER: P13L11-12: What is meant with 'any other atmospheric phenomena'? Furthermore, the following text relates the attenuation to the humidity which is an atmospheric phenomena. The whole meaning of this sentence is, therefore, unclear.

RESPONSE: restated: "by any one atmospheric phenomenon as described in the previous sections"

REVIEWER: P13L15-22: The antenna drying times might be very much influenced also by other environmental variables such as wind or sun radiation. Could e.g. wind which is also displayed in the figs 16 and 17 explain part of the uncertainty in drying duration? Is there any reason why humidity is included in the quantitative analyses and not the wind?

RESPONSE: While an interesting topic, this would go beyond the scope of this paper. We will mention in the text that these phenoma could indeed influence the antenna drying times and that this is subject of future work.

REVIEWER: P14L20: A robust evidence that the link response to the additive and multiplicative bias is consistent over different events has not been provided in the previous text. Why don't you e.g. quantify both additive and multiplicative bias for each event and link and provide information about range and variability of both types of biases?

RESPONSE: Our statement refers to P9L5-14 and fig. 7. We feel that this provides enough evidence to make this statement. Computing these biases for each single event in the data set is beyond the scope of this paper.

REVIEWER: Figures: There is a wrong legend in the panel (a) of the figures 5, 6, 8, 9, 10, 12, 15, 16 and 17 as RAL 38 V is assigned to both blue and green lines. It seems to be that green line belongs to the RAL 38 H and the orange one to the RAL 26 V, i.e. same coding as in the panel (b)

RESPONSE: We thank the reviewer for catching this error! We will correct this.

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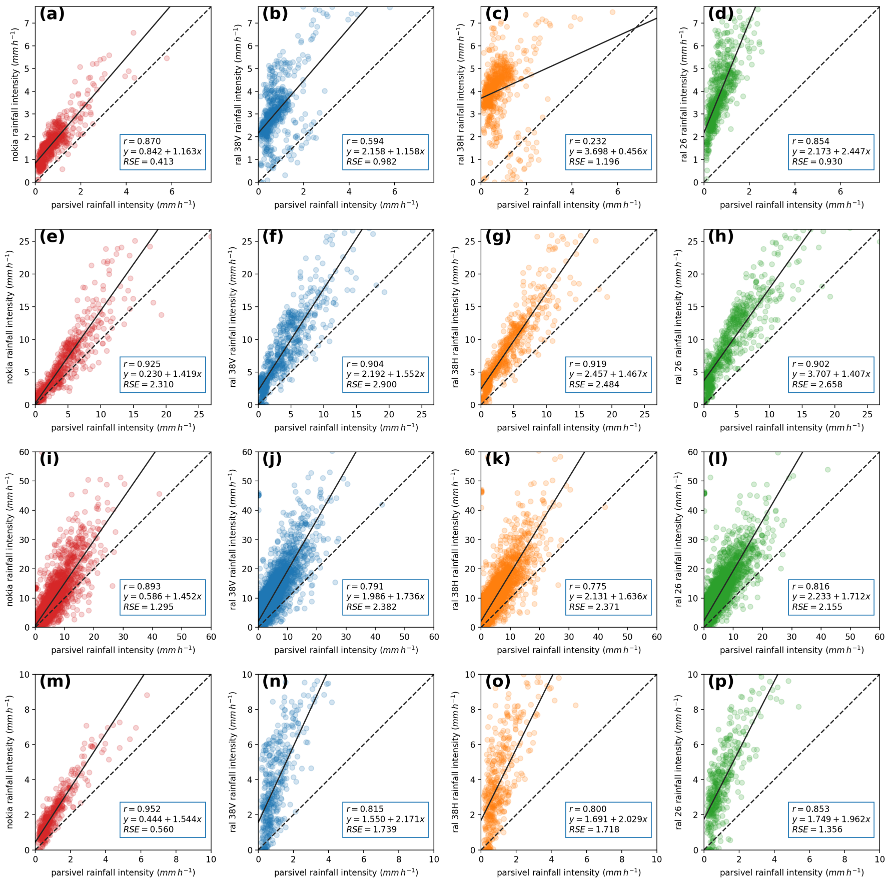

Fig. 1. scatterplots of link-derived rainfall intensities versus disdrometer-derived rainfall intensities

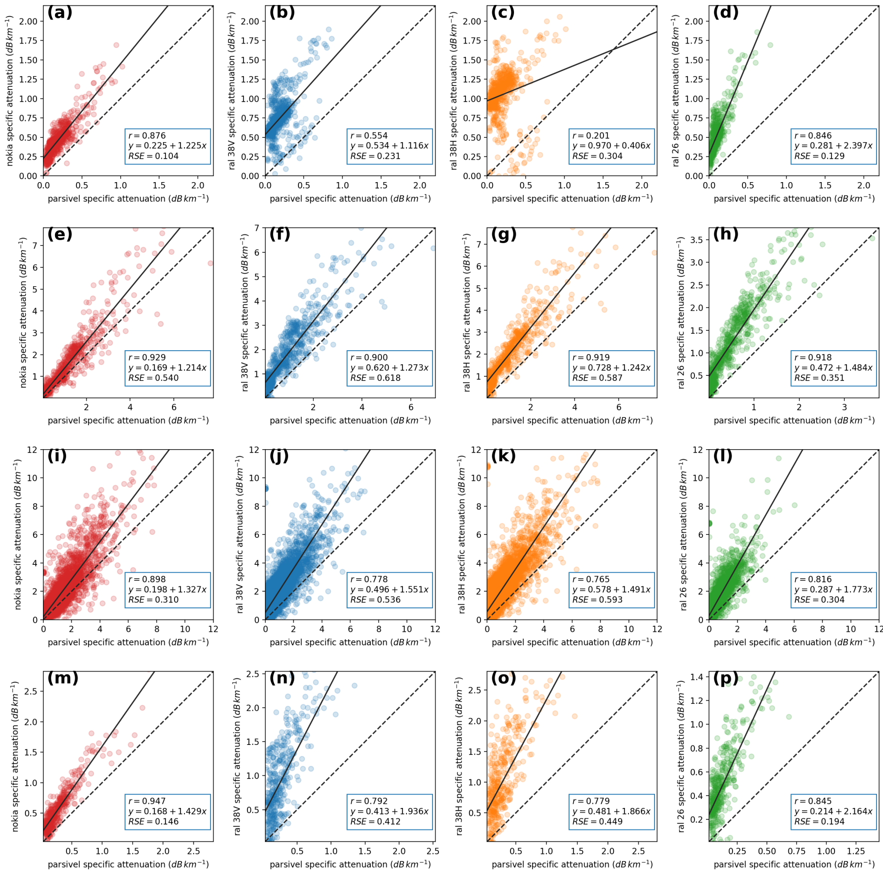

Fig. 2. scatterplots of link attenuation versus disdrometer derived attenuation